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Richardson Number (RiNo) Float Operations during the Patch Experiment (PATCHEX), and Data Summary

by

Ellyn T. Montgomery

November 1988

Technical Report

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Woods Hole, Massachusetts 02543

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Albert J. Williams 3rd, Chairman
Department of Ocean Engineering

ABSTRACT

The Patch Experiment (PATCHEX) was a multi-ship experiment that took place in the area near 34 N, 127 W, between 8 and 27 October, 1986. The ships used in the experiment and their chief scientific objectives were the following: R/V THOMPSON, AMP (Advanced Microstructure Profiler) and MSP (micro-structure profiler) drops; USNS DESTEIGUER, ADCP (Acoustic Doppler Current Profiler), Seasoar and RiNo (Richardson Number) float operations; R/V POINT SUR, ADCP and towed fish; and FLIP, Acoustic Doppler and CTD profiling.

This report describes the RiNo operations carried out on the USNS DESTEIGUER. Topics discussed include the RiNo float, the sensors used, how it was tracked, some of the preliminary results, and a log of the relevant parts of USNS DESTEIGUER Cruise #84.

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1. INTRODUCTION

The Patch Experiment (PATCHEX) took place between 8 and 27 October, 1986 in the eastern North Pacific Ocean near 34 N, 127 W. Figure 1 shows the PATCHEX operations area. The participants from the Woods Hole Oceanographic Institution (WHOI) deployed and recovered an instrument designed at WHOI by Albert J. Williams III and Chris H. Converse to measure Richardson number in the ocean. The instrument, dubbed the RiNo float, is a neutrally buoyant free vehicle that behaves like a Swallow float, that is, approximately isobaric, but with some vertical response to isopycnal motion. It measures shear and density gradient over one to five meter vertical separations. The RiNo float itself, the sensors used, and the data structure are described in greater detail in the second section of this report.

The Richardson number, $Ri = N^2/S^2$, where N is buoyancy frequency (related to density gradient) and S is vertical shear, is important to oceanographers as an indicator of a fluid's stability. Richardson numbers of less than 1/4 indicate that vertical shear instabilities may cause overturning and mixing. The PATCHEX area was expected to be an area of substantial mixing in the upper pycnocline, so intensive sampling and observation effort was scheduled for this area. Unfortunately, for much the experiment, the conditions were relatively quiet and little mixing was observed.

After a test deployment on October 10, the RiNo float was deployed October 12 and followed the water mass at nominally 190 meters depth for a total of nine days. During the RiNo's deployment, the float's depth varied betweeen 175 and 205 meters, but for most of the deployment, it remained within a few meters of 190. During the deployment, initially near the moored FLIP, the RiNo drifted about 11 miles in a northerly direction. The method used for tracking the RiNo is discussed in the third section.

The data obtained from the RiNo were very good, especially for a newly developed instrument, but there were a few problems which fortunately did not impact the data significantly. Time series of velocity were obtained from each of the six sensors, but only six of the eight thermistors functioned correctly throughout the deployment. The Seabird Seacat CTD worked until its memory was filled, which happened prematurely because the remaining memory on board was not correctly addressed. This problem was corrected by the manufacturer after the cruise. The other equipment malfunction occurred in the variable buoyancy unit (VBU), which controls buoyancy adjustment after deployment. This malfunction was observed during the test deployment, so before the actual deployment, the ballast was carefully adjusted, so that the float settled to the desired depth. The problem with the VBU did not affect data quality. The data collected by the RiNo float is described in Section 4.

A cruise log summarizing the activities of the entire cruise is presented in the final section of this report.

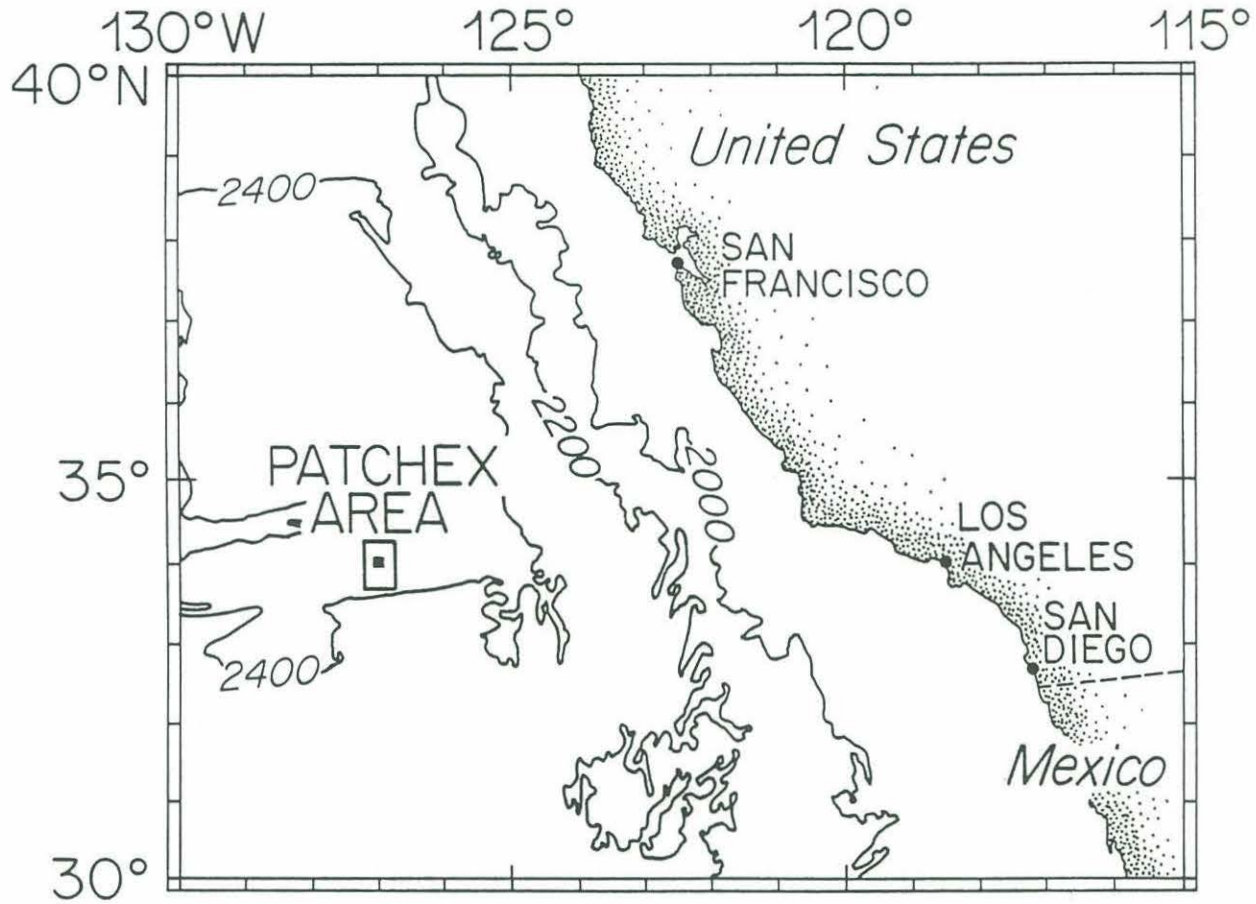

Figure 1 - Chart showing the location of the PATCHEX area.

2. RICHARDSON NUMBER (RiNo) FLOAT

2a. Instrument Description

The RiNo (Figure 2) is a neutrally buoyant free vehicle that collects velocity, temperature, conductivity, pressure and spatial orientation data. The total height of the instrument is 5 meters, and at the widest point (the central buoyancy unit), the RiNo measures 1.54 meters. When in the water, the RiNo floats with the long axis vertical. The velocity sensors and thermistors are arranged on the towers with .5 to 5 meter separations. The orientation sensors (pitch, roll and compass direction), are located inside the BASS controller unit. The conductivity, pressure, and another temperature sensor are located on a Seabird Seacat CTD, mounted on the central buoyancy unit. A flag, a strobe light, and a VHF radio beacon are attached to the uppermost tower section to aid in locating the vehicle for recovery. The RiNo float and its instrumentation are described in the paper by Williams, Converse, and Nicholson (1987), and in the WHOI Technical report by Converse (1988).

The RiNo float is a modular system based on BASS (Benthic Acoustic Stress Sensor) instrumentation. A detailed explanation of BASS components and their workings is presented in Williams et al., 1987. A general description of the BASS system as it relates to the RiNo float follows. The components making up a BASS are the following: a controller module that handles data aquisition and averaging, a data logging unit containing one or two cassette recorders, a battery module, and sensor towers containing six velocity sensors, and, in the case of RiNo, eight thermistors.

The velocity sensors used in BASS are Acoustic Current Meters designed by A.J. Williams 3rd. Each BASS velocity sensor (or "pod") is comprised of four pairs of acoustic transducers mounted diagonally across from each other on the frames of the tower segments. One member of each pair is located on the upper ring, with each transducer separated from the next by 90 degrees. The corresponding member of each pair is located on the lower ring, rotated 180 degrees from the one on the upper ring, providing a diagonal orientation.

Determination of current speed and direction is made using the differential travel times of an acoustic pulse between each diagonal pair of transducers. Figure 3 shows a typical BASS velocity sensor. The tower segments can be put together in any order, and for PATCHEX, three sensors were placed above the buoyancy unit, and three placed below it. The sensors are connected by cables to the BASS controller unit in the central buoyancy module. BASS acquires 2 Hz (0.5 second) sampled data, averages them over two minutes, and records the two minute averages. The logger will also record the 2 Hz data without averaging for one hour, if a high temperature variation event triggers it to do so. These unaveraged data are called "event" data, because the recording is triggered by an event. The BASS logger used for RiNo produced two cassettes; one containing averaged data for the entire deployment, the other containing four files of unaveraged event data. The variance of the seventh thermistor was used to trigger events, with the trigger threshold increased by a factor of 2 after each event. During PATCHEX, four events were recorded, the last of which was triggered by the RiNo's ascent to the surface for recovery.

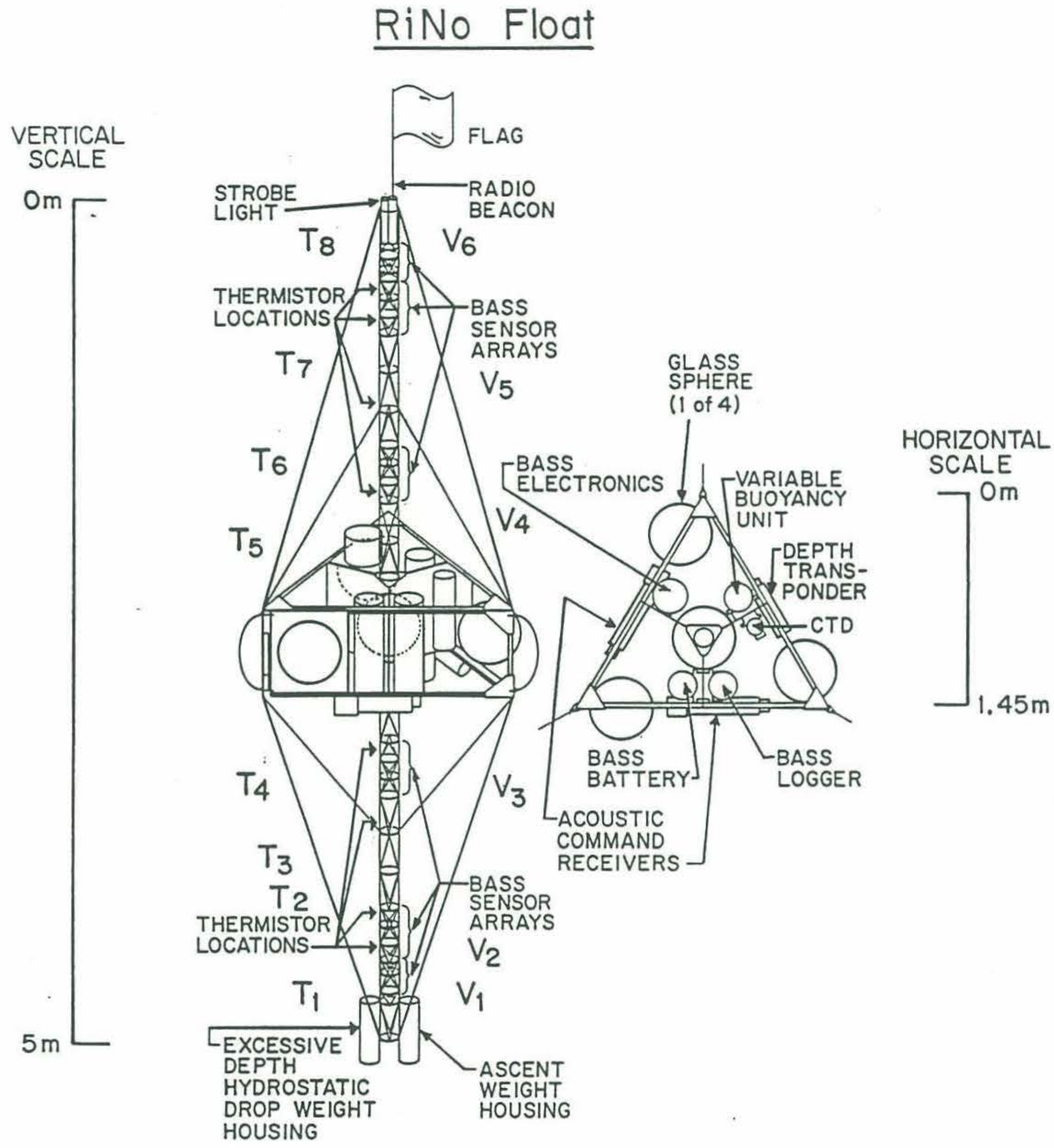

Figure 2 - Schematic of the Richardson Number Float.

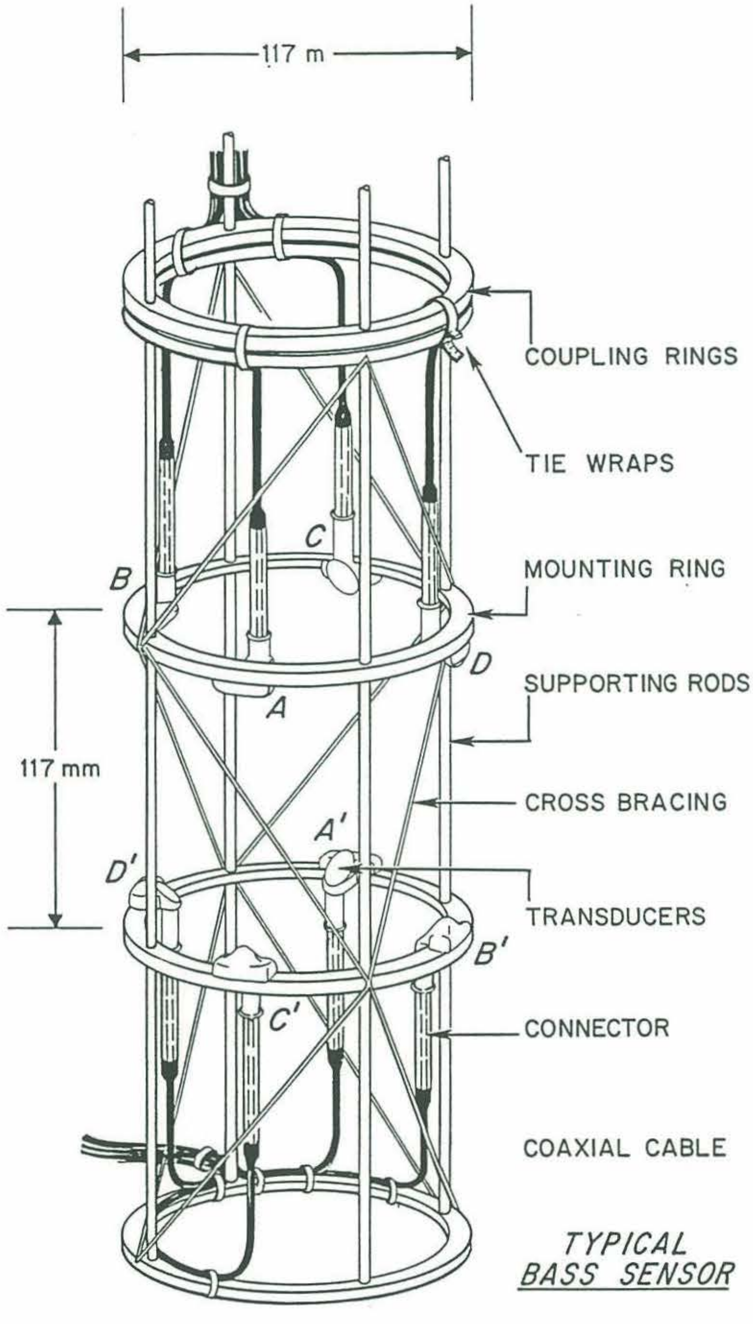

Figure 3 - Diagram of a typical BASS sensor cage.

As shown in Figure 2, there are also eight glass thermistors attached to the RiNo float's towers. Unfortunately, two broke during the test deployment, leaving six for the actual experiment. The data from these are also acquired, averaged and logged by the BASS, at the same rates described above. Their response time is 16 miliseconds.

The Seabird Seacat CTD is a compact conductivity, temperature, and pressure profiler that stores the data collected in solid-state memory. This instrument was also mounted on the central buoyancy module. At the surface, a serial interface was used for communications and data retrieval. The sampling rate used during PATCHEX was 60 seconds. The Seacat CTD was a new instrument at the time of deployment and it worked well, except that its additional memory (the manufacturer's option of 256K memory was installed instead of the basic 64K) was not accessible because of a programming fault in the system EPROM; consequently, the usable memory was full after 3 days, and no data were stored for the last six days of the deployment.

2b. Data Format

The averaged data from the six velocity sensors, eight thermistors, and orientation sensors were stored on a Verbatim H300 NH casstte tape in the BASS logger. The format for these data is as follows:

Average tape - length EF bytes, or 478 characters

	X0	X2	X4	X6	X8	XA	XC	XE
0X	M D	H M	V11	V12	V13	V14	V21	V22
1X	V23	V24	V31	V32	V33	V34	V41	V42
2X	V43	V44	V51	V52	V53	V54	V61	V62
3X	V63	V64	T1	T2	T3	T4	T5	T6
4X	T7	T8	Q1Q2	Q3Q4	Q5Q6	R111	R112	R113
5X	R114	R122	R123	R124	R133	R134	R144	R211
6X	R212	R213	R214	R222	R223	R224	R333	R334
7X	R244	R311	R312	R313	R134	R322	R323	R324
8X	R333	R334	R344	R411	R412	R413	R141	R422
9X	R423	R424	R433	R434	R444	R511	R512	R513
AX	R154	R522	R523	R524	R533	R534	R544	R611
BX	R612	R613	R614	R622	R623	R624	R633	R634
CX	R644	TT11	TT12	TT14	TT18	TT22	TT24	TT28
DX	TT44	TT48	TT88	TT33	TT35	TT36	TT37	TT55
EX	TT56	TT57	TT66	TT67	TT77	PTCH	ROLL	ZN -

In this representation of the format, the first two two-byte hexadecimal words (M D and H M) are record identifiers for: month, day, hour, minute.

The remainder of the record is stored in binary coded decimal (BCD). The next set of 24 two-byte words are the differential travel times from each of the four transducer pairs at each of the six sensors. In the format description above, V stands for velocity, the first number is the sensor pod number, and the second number stands for the axis (1 for A, 4 for D). U,V, and W velocity vectors are computed from three of the axes, the fourth is redundant. It can be used in case of the failure of one of the other 3 axes to compute the velocities. The following eight two-byte words contain the resistance values from the eight thermistors. The thermistor data in the format description is represented by Ti, where T stands for thermistor, and i stands for thermistor number. Six one-byte words follow, containing data quality information for each sensor pod. The middle of the record is comprised of 60 velocity cross products, and 20 temperature cross products. These are represented in the format description as Rixy, or TTij. For the velocity components, R stands for Reynolds stress product, i is the pod number, and x and y are the axes to be multiplied. For example, R124 is the value obtained when the velocitites from pod 1, axis 2 (B) and pod 1, axis 4 (D) are multiplied. For the thermistors, TT indicates a temperature cross product, i and j are the thermistor values multiplied. The last three words of each record are pitch, roll and compass direction, in degrees.

The 1-hour records for the unaveraged event data are necessarily smaller than the averaged data, to allow as much as possible to fit on a cassette. The cross products and quality words are omitted, and instead of having an averaged value for axis i of sensor j, the value is unaveraged.

The following is the format of the unaveraged data:

Event tape - Length 47 bytes, or 142 characters

	X0	X2	X4	X6	X8	XA	XC	XE
0X	CNTR	V11	V12	V13	V14	V21	V22	V23
1X	V24	V31	V32	V33	V34	V41	V42	V43
2X	V44	V51	V52	V53	V54	V61	V62	V63
3X	V64	T1	T2	T4	T8	T3	T5	T6
4X	T7	PTCH	ROLL	ZN-				

In the event format there is a counter in each record instead of actual time words. There is supposed to be a header record at the beginning of each event file that contained month, day, hour, and minute, but, in PATCHEX, it never got written, and the events did not get separated into individual files. This problem with the Eprom has been corrected, but made processing the PATCHEX data unusually complicated. To find the beginning of each event file, the counter and sequential number of each record had to be examined to find out where the jumps occurred, then the averaged data was examined to find where the temperature variance changed enough to trigger an event record. These two critia determined when each event data file started.

The data is removed from cassette directly to 9 track tapes. The time differences are then converted to east, north and vertical velocity components, in cm/sec. The resistance values from the thermistors are converted to temperature, in degrees centigrade. These processing steps are performed on a Digital Computers VAX mainframe, with Fortran software. The processing will not be discussed in this report.

3. RiNo TRACKING

Once the RiNo float is deployed, the task becomes keeping track of its position. Since the RiNo is neutrally buoyant at the depth where it settles (determined before deployment by adjusting the net buoyancy), it moves with the water at that depth. During PATCHEX, RiNo stayed between 175 and 205 meters depth, and over the nine days deployed, traveled an end-point to end-point distance of approximately 11 nautical miles. Not all this time was spent tracking RiNo. Once the speed and direction of movement were established, the ship could be used for other work, with only periodic checks on the RiNo's position. This permitted the plotting of the general path of the track. During the first two days of tracking, the ship was not committed to other work so a detailed plot of the RiNo's movement was obtained. Later, only occassional points were possible.

The RiNo float is tracked acoustically, using the ship's echosounder and depth recorder (Raytheon PTR), and RiNo's transponders. The PTR settings most often used were the following: a program of length nine was set to transmit on 1 and listen on sweeps 2-9, and the scale was set to 0-750 meters (returns in the second cycle were detectable for the 750-1500 meter range). The 12 kHz echosounder on the ship transmits a signal which RiNo returns at 12.5 kHz. The travel time of this sound pulse to the ship provides the means of calculating slant range to the RiNo. The depth of the float is determined by the time taken by the surface echo of the RiNo's 12.5 kHz reply to excite a second (11.5 kHz) transponder on RiNo, which shows as a second return on the PTR record. Figure 4 shows the paths of the transmissions.

The calculation of the depth and slant range are made using the output of a Line Scan Recorder (LSR); an example is shown in Figure 5. There should always be two traces visible; the upper one corresponds to the slant range, and the lower one corresponds to the range plus the depth of the RiNo. The slant range is obtained by measuring from the LSR plot origin to the upper trace, and using the appropriate scale to convert to meters. The depth is computed by measuring the distance between the tops of both traces, and converting to meters using the horizontal scale of the LSR. With the slant range and depth, the hypotenuse and one leg of a right triangle are known (Figure 4), so the surface range can be calculated.

Now the surface range and depth of the RiNo are known, but the bearing from the ship is not. By turning the ship and observing whether the float gets nearer or farther away as a result of the move, the direction to the RiNo can be established. When the range to the RiNo reaches a minimum, it is said to be the closest point of approach (CPA), and at this point the RiNo is abeam of the ship. For example, the RiNo is at 200m depth, with range of 600m, and the ship is moving north. We need to determine whether the RiNo is east or west of the ship. While steaming north, the range decreases to the CPA of 450m, then starts to increase. As soon as the slant range is observed to increase (as soon as the peak on the LSR trace is passed), the ship is turned to a heading of 090 degrees (east). If the range starts to get smaller again, the RiNo must have originally been east of the ship, and now is south (to the right) of the ship. If the turn had been made to the west, and the float was actually east of the ship to begin with, the range would continue to increase, and the tracker would conclude

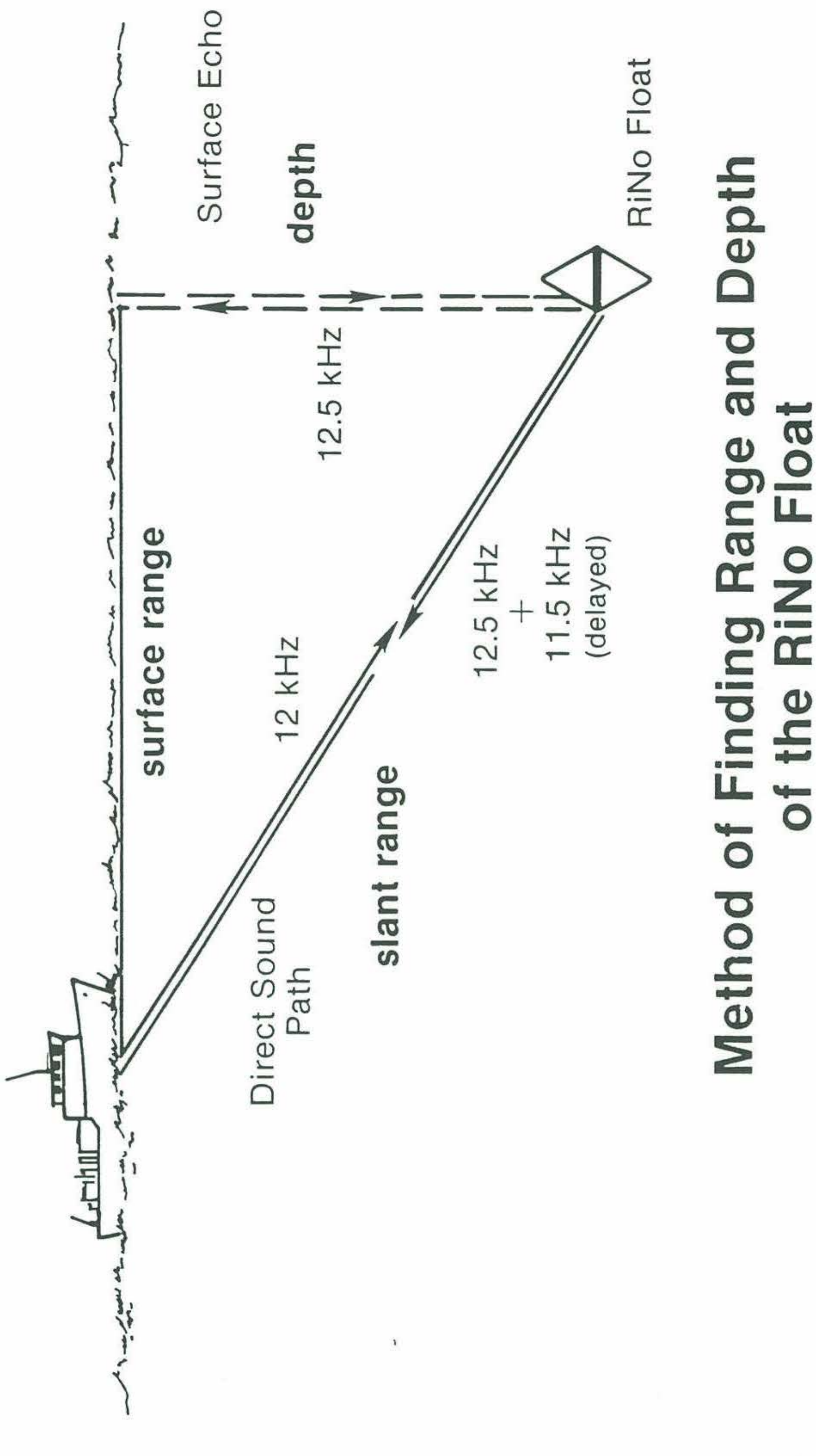

Figure 4 - Diagram of the acoustic paths used in determining the depth and range of the RiNo.

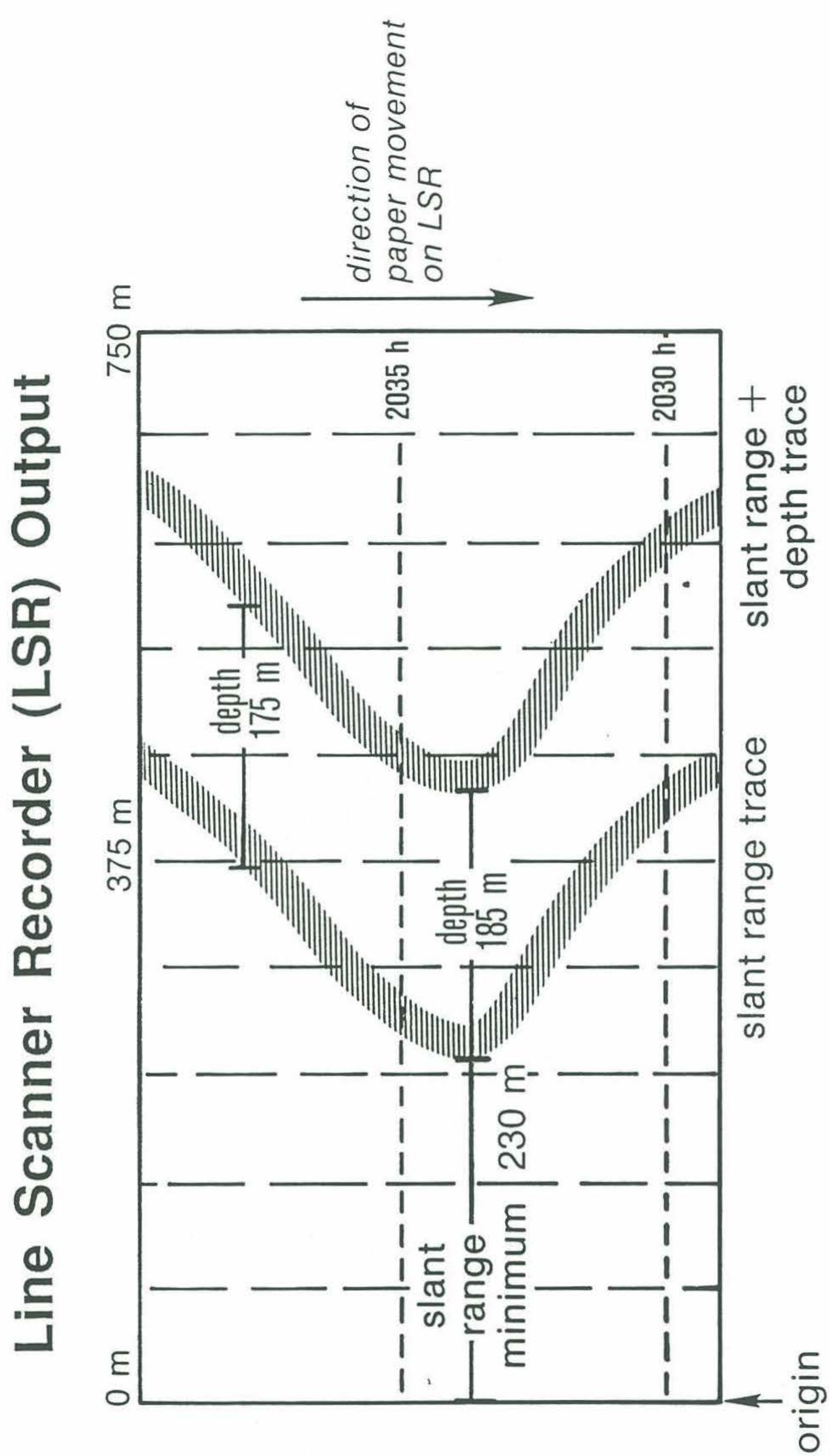

Figure 5 - Example of a Line Scan Recorder trace, from which the RiNo's depth and range are computed.

that the "wrong" turn had been made, and change course appropriately. Once the RiNo's position relative to the ship is established, one can obtain a series of fixes closely spaced in time by continuing to turn 90 degrees immediately after each minimum range value is observed.

While all the above is going on, the ship's positions and the relative positions of RiNo have to be plotted. Keeping a running cruise track, and adding the RiNo's position each time a CPA surface range is observed has worked fairly well. This is exceedingly tedious to do for long periods, but is necessary especially immediately after deployment, just before recovery, and when the RiNo is moving rapidly and unpredictably.

A Trimbull 10-X navigation system provided by the Naval Research Laboratory team was used on the USNS DESTEIGUER. It was able to provide GPS (Global Positioning System) or Loran fixes, depending on the program used. GPS, a satellite based positioning system, is the more accurate navigation system, but was not available 24 hours per day. The Loran stations on the west coast did not provide adequate coverage for the PATCHEX area; all the possible combinations of available stations were tried, and still, the positions obtained were only reasonable for part of the day. On average, we had marginal Loran coverage for 15-16 hours a day, and between midnight and about 0900 local time, the skywave fixes were basically useless. Good GPS coverage for the area was usually available. The RiNo's position could therefore be determined reliably during the hours of about 0900 and 2000 local.

When tracking the float intensively, as described above, the errors came primarily from bad navigation fixes.

4. RESULTS

Despite an unfortunate collision with the DESTEIGUER during the test deployment, the RiNo float succeeded in providing a useful data set. A cassette of averaged velocities and temperatures was written, four events were recorded on another cassette, and RiNo's movements were documented throughout the cruise.

Figure 6 shows the path RiNo followed during the nine days deployed. The RiNo float was tracked intensively for the first three days, during which time it was observed to make two complete loops of inertial period. Though the tracking effort was lessened at about the time the float's movement became simpler, we do not believe that the simplification of the float's track was caused by decreased tracking effort. The dotted lines indicate the times when the RiNo float's position was checked infrequently, and thus the exact path of movement is not known.

An initial deployment of the RiNo on 10 October with the sensors covered, to obtain zero data for calibration of the velocity sensors was also used as a CTD cast to establish the characteristics of the water mass. The Seacat CTD provided data from which profiles of temperature (T), salinity (S), potential density (σ_θ), and buoyancy frequency (N) were plotted. Figure 7 shows these profiles, and the corresponding T-S and T-σ_θ curves. These relationships show the water in the RiNo float's depth range (180 to 200 meters) to be free of inversions, diffusively stable, and with a very tight T-σ_θ relationship.

The time series plot of two minute averaged velocity at each sensor, shown in Figure 8 [V (north/south) component, top: and U (east/west) component, bottom], indicates that the low-frequency near-inertial oscillations in velocity ceased on October 17. This supports the idea that lessening our tracking effort was not the cause of the change in the RiNo's path shown in Figure 6. Also, because the measurements were made relative to the float, the velocities observed are smaller near the central buoyancy unit, and the velocities recorded by the sensors above the center are 180 degrees out of phase with those recorded by the sensors below the center; this is consistent with the float moving horizontally with the large-scale water motion while measuring the smaller-scale vertical shear relative to it.

A problem was encountered with the calibration coefficients for the thermistors. The coefficients obtained from a pre-cruise water bath calibration, when applied to the data, did not appear to appropriately correct the data. Thermistors 5 and 4 (those immediately above and below the buoyancy unit) were the most obviously off, both being cooler than expected. These two sensors were corrected so that the time averaged temperature profiles from the float had a uniform vertical gradient. In addition, to force the thermistors' temperature versus depth profiles to intersect with that of the CTD, an offset of 0.137 was subtracted from each thermistor. The thermistor data corrected in the way described above is reasonably good. In the future, more care should be taken with getting accurate the pre- and post-cruise calibrations.

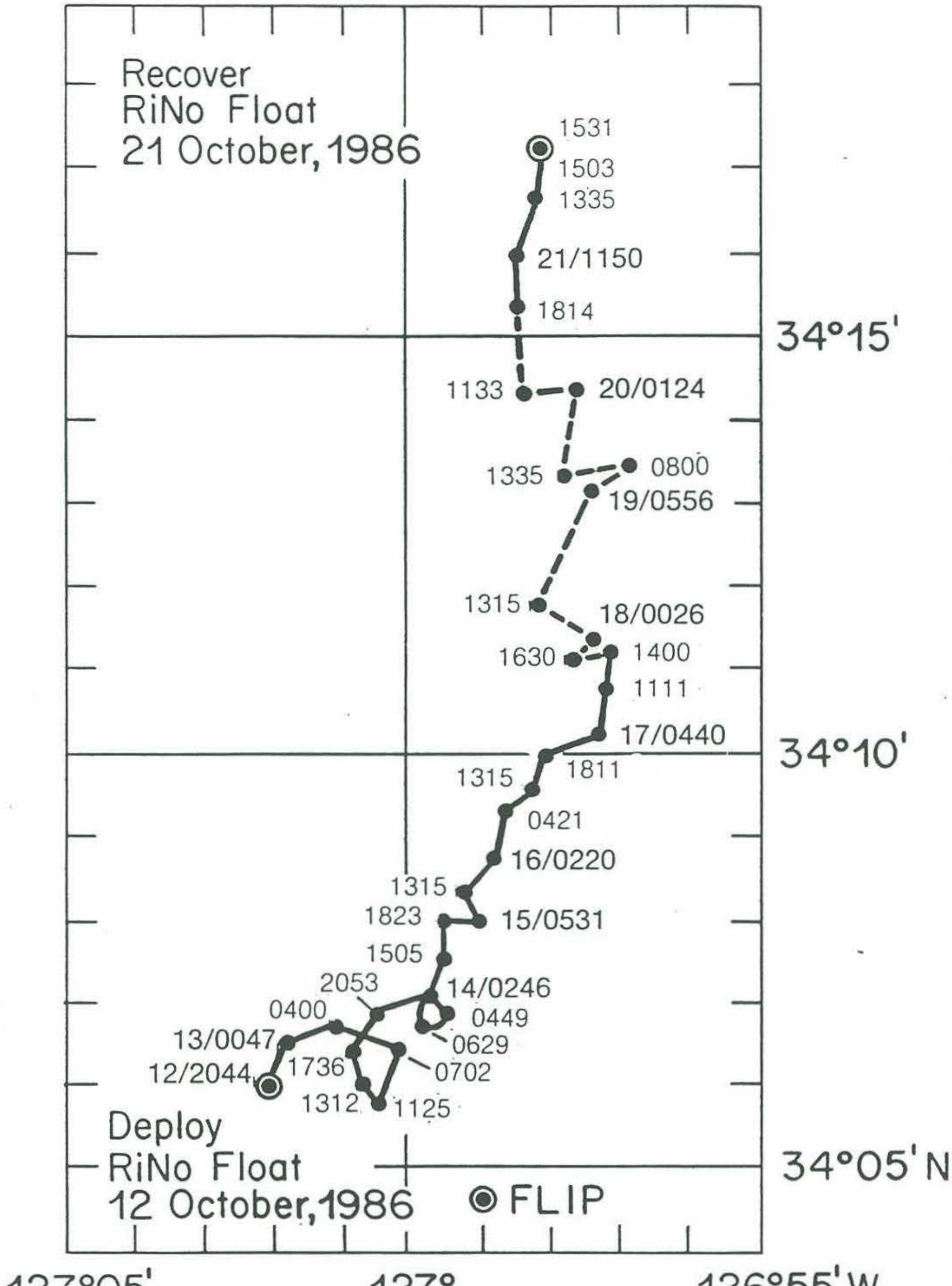

Figure 6 - Path of RiNo float movement during the PATCHEX deployment.

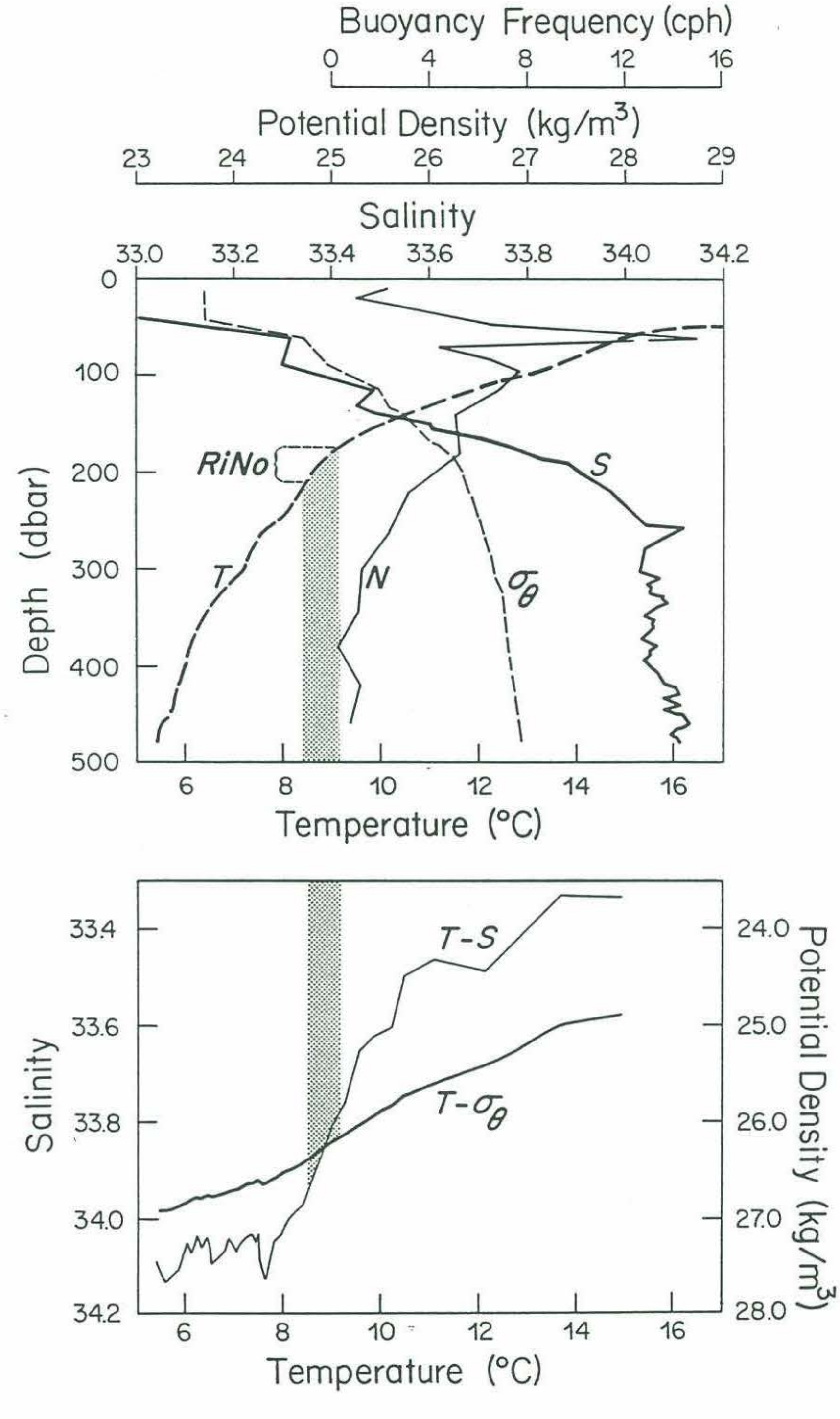

Figure 7 - A pre-deployment CTD profile of PATCHEX area, showing water column characterstics is presented in the top frame. The T-S and T-σ_θ relationships derived are shown below.

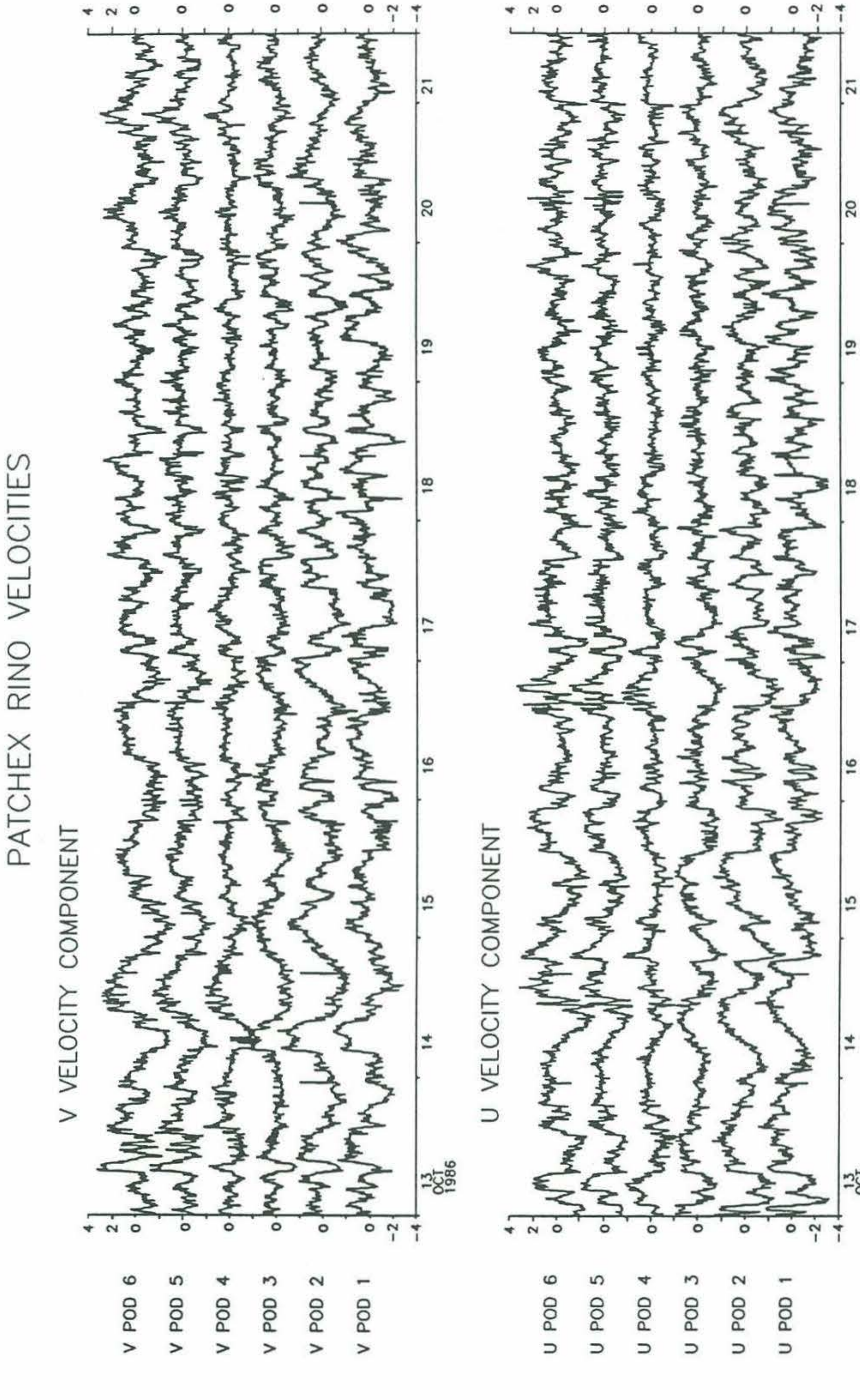

Figure 8 - Time series of U (bottom frame) and V (top frame) velocities at each sensor on RiNo (Pod 1 lowest, Pod 6 highest in each plot), during the PATCHEX deployment.

Figure 9 is a plot of temperature variation of the top and bottom thermistors over the duration of the deployment. The data displayed was corrected by the process described above. A well defined semidiurnal tide is evident, shown by the water temperature varying .25 degrees over the 5 meter height of the RiNo float as it makes its vertical excursions in the water column. The upper heavy line shows the data from the top thermistor and the lower line shows the data from the lowest thermistor in the array.

Shear was computed using the BASS velocity data. The difference in velocities at sensors X and Y, divided by the distance between X and Y, was calculated to provide shear. All possible combinations of sensor separtions were analysed, but those with separations of less than 50 cm were not used because the noise level was significantly higher than the signal at this close spacing.

Values for N^2 were inferred from the thermistors and the $\delta\sigma_\theta/\delta T$ relationship in Figure 7. Had the Seacat CTD worked throughout the experiment, direct density data would have been available; fortunately it worked long enough to provide a $\delta\sigma_\theta/\delta T$ curve.

Froude number $\delta V/\delta Z/N = Ri^{-1/2}$ is plotted instead of Richardson number to emphasize the shear contributions. The plots shown in Figure 10 were made using velocity data from sensors 4 and 3, and temperature data from thermistors 2 and 6. The top frame shows a time series of vertical shear ($\delta V/\delta Z$), plotted with a solid line, and twice buoyancy frequency (2N), plotted with a dotted line. The bottom frame shows a time series of Froude number. When the Froude number is greater than 2, the Richardson number is less than 1/4, indicating potentially unstable water. As shown in Figure 10, the Froude number was greater than 2 only four times during PATCHEX, and all occured before October 18, i.e. during the time when the velocities were dominated by near inertial fluctuations. The shear, shown in the top frame of Figure 10, is also larger and more variable during this time.

The times when Froude number was large were selected for further analysis to see whether any temperature inversions could be observed. Several small scale, short duration inversions were observed near the times when the Froude number was high. Unfortunately, due to the problems calibrating the thermistors, it is impossible to determine whether these small inversions are real or introduced by the processing.

None of the four event files recorded by BASS corresponded to times of high Froude number. The three real events were recorded before October 14, when the first high Froude number was recorded, and the last event was triggered by the ascent for recovery on October 21. The event data recorded during PATCHEX was relatively uninteresting, partially because the time scale of the events was very short, and partially because the trigger thresholds were set a little low for the area.

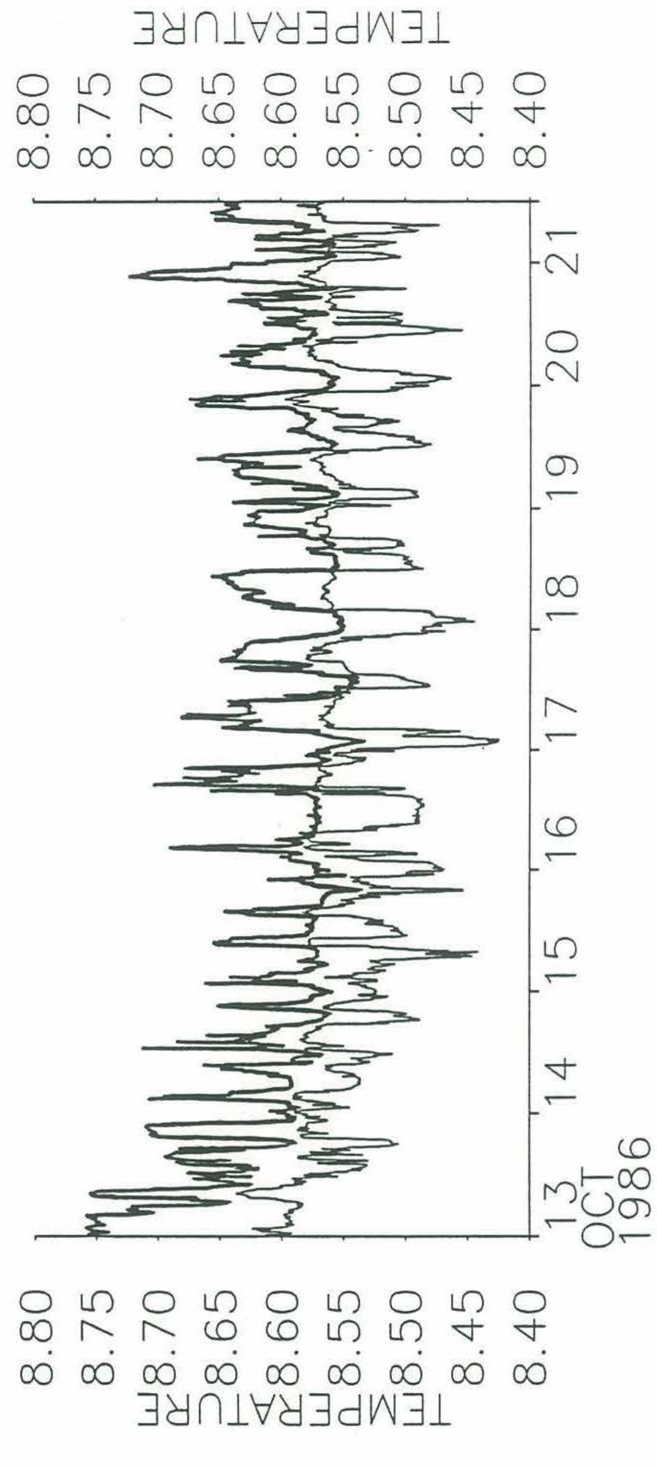

Figure 9 - Temperature time series from thermistors 1 and 8. The thick line shows the top thermistor on the float (#8) and the thin line shows the bottom thermistor (#1).

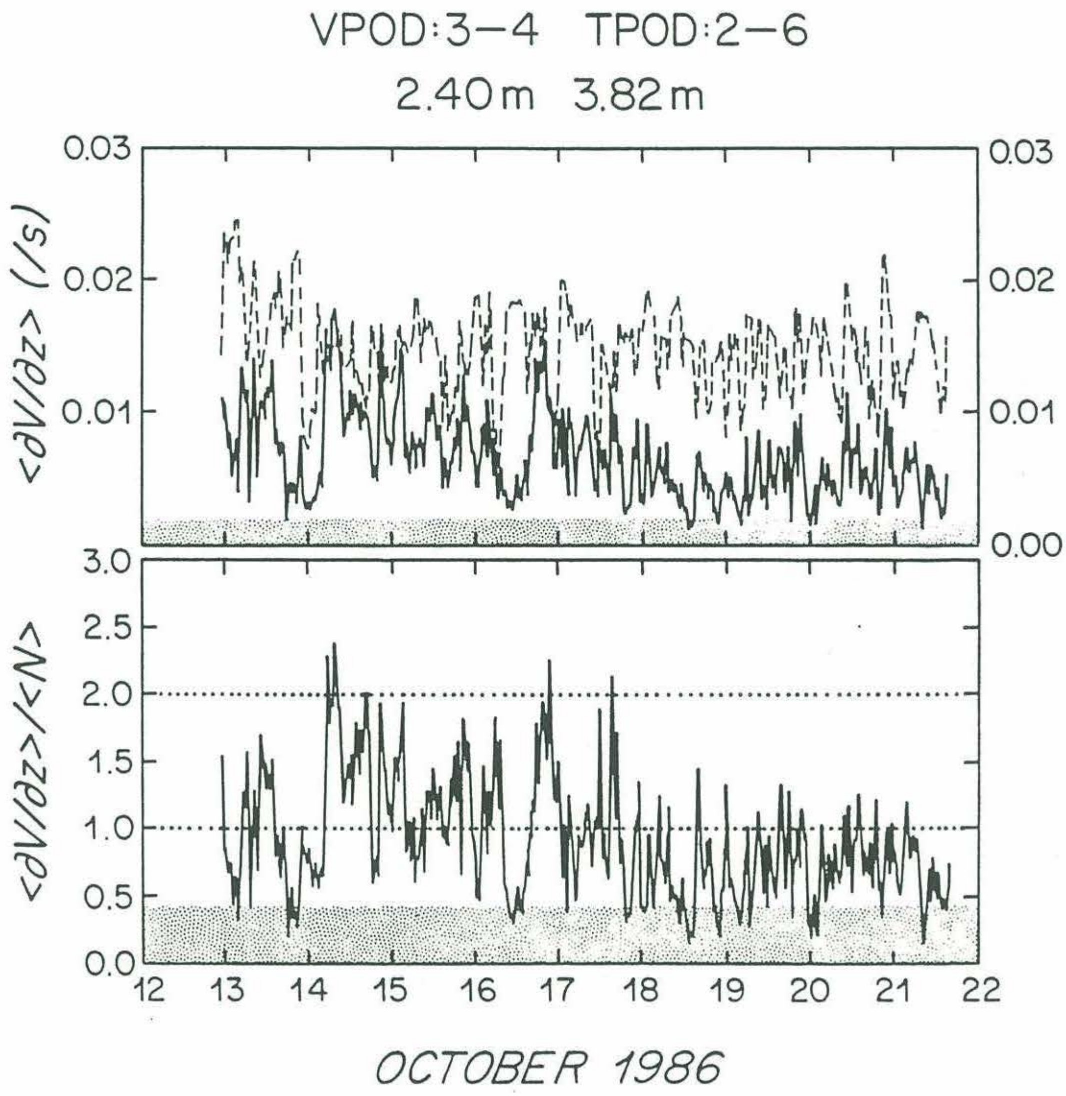

Figure 10 - A time series plots of vertical shear (solid line) and twice buoyancy frequency (dotted line) is shown in the top frame and Froude number calculated between velocity sensors 3-4 (2.4 m separations) and thermistors 2 and 6 (3.82 m separation) versus time is shown in the bottom frame.

5. LOG OF USNS DESTEIGUER CRUISE 84

October 8 - October 26, 1986

October 8, 1986	(times listed as GMT)
1900h	Depart NSC pier Oakland, CA.
1900-0000h	En route to 34N, 127W.
October 9	
0000-2200h	En route to 34N, 127W.
2300h	Preparing for half-inertial period doppler (ADCP) log triangular pattern around FLIP.
October 10	
1500h	Attempted 1st launch of RiNo (for zeros). Aborted because A-frame brace stressed a guy wire on the bottom tower, causing one of the tower segments to collapse.
1530h	Repairs to RiNo commenced.
1630h	NRL CTD cast.
1730h	Rino repairs completed.
1800h	2nd attempt at deployment for zero values successful.
1830h	RiNo at 190m and more or less stable
2015h	Sent weight drop command to start Rino to surface
2052h	Heard RiNo radio signal (RiNo at surface).
2125h	Sighted Rino.
2230h	Rino on deck; sustained significant damage to both towers due to ship hitting RiNo twice during recovery.
2245h	Repairs to RiNo commenced.
October 11	
1500h	Continued RiNo repairs
2130h	Checked out Seacat CTD data from zero run. Seacat worked as hoped. Did not reinitialize memory, due to ample anticipated storage space.
October 12	
1400h	Finished all repairs on RiNo.
1830h	Prepared deck area for "real" RiNo deployment.
2044h	RiNo successfully deployed at: 34 06.04 N, 137 02.00 W
2057h	Descent weight dropped
2100h	Began intensive tracking of RiNo using PTR & LSR
2359h	RiNo settled to a consistent depth of 188m.
October 13	
1200h	Continued tracking Rino: have gotten good close passes, confident of position and direction of movement.
1610h	Left constant RiNo tracking for acoustic doppler calibration runs.
1736h	RiNo heard in passing, continuing calibration runs.
1925h	Found RiNo where expected after calibration runs: continuing intensive tracking.
2054h	Seasoar tows commenced.

October 14	
0130h	Seasoar recovered.
0200-2300h	Resumed tracking RiNo: Seasoar being worked on.
2310h	Seasoar deployed and towing commenced.
2315h	RiNo tracking effort lessened.
October 15	
0000-1619h	Continued towing Seasoar and tracking RiNo when possible.
1620h	Seasoar brought on deck for more modifications.
October 16	
0000-1340h	Continued tracking RiNo; Seasoar being worked on.
1345h	Deployed Seasoar for more tows. Continued tracking RiNo when passing last known position.
2200h	Recovered Seasoar; continued tracking RiNo.
October 17	
0210h	Redeployed Seasoar for more towing.
1740h	Leave RiNo with R/V THOMPSON nearby, to go tow Seasoar near FLIP.
October 18, 19 and 20	
0000-2359h	R/V THOMPSON continued monitoring RiNo position. USNS DESTEIGUER continued towing Seasoar between FLIP and R/V THOMPSON.
October 21	
0000-1200h	Same as above.
1230h	Due to forecast of increasingly foul weather, decision to recover RiNo was made.
1235-1250h	Recovered Seasoar.
1300h	Steamed toward RiNo's expected position and found it.
1315-1500h	Tracked RiNo to determine direction of movement.
1507h	Gave weight release command.
1530h	RiNo on surface 100 yds from DESTEIGUER.
1611h	Recovery of RiNo completed.
2030h	BASS tapes look okay; Seacat only recorded data for first 3 days of the 9 day deployment in addition to previously recorded data from zeroing run.
0215h	Deployed Seasoar for towing around FLIP.
0230-2359h	Continued towing Seasoar.
October 23	
0000-2359h	Continued towing Seasoar.
October 24	
0135h	Recovered Seasoar.
0520h	Deployed Seasoar for last tow.
2300h	Recovered Seasoar.
2315h	Commenced steaming to San Diego.
October 25	
0000-2359h	En route to San Diego.
October 26	
0900h	At dock in San Diego.

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The Patch Experiment (PATCHEX) was a multi-ship experiment that took place in the area near 34 N, 127 W, between 8 and ctober, 1986. The ships used in the experiment and their chief scientific objectives were the following: R/V *Thompson*, AMP anced Microstructure Profiler) and MSP (micro-structure profiler) drops; USNS *Desteiguer*, ADCP (Acoustic Doppler Current ler), Seasoar and RiNo (Richardson Number) float operations; R/V *Point Sur*, ADCP and towed fish; and FLIP, Acoustic Doppler CTD profiling.

This report describes the RiNo operations carried out on the USNS *Desteiguer*. Topics discussed include the RiNo float, the ors used, how it was tracked, some of the preliminary results, and a log of the relevant parts of the USNS *Desteiguer* Cruise #84.

cument Analysis a. Descriptors

iNo Float
ichardson Number
ficrostructure measurement

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